

Nothofagus dieback on Mt. Giluwe, Papua New Guinea¹

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ABSTRACT: The phenomenon of patch dieback in stands of *Nothofagus* on Mt. Giluwe, in the southern highlands of Papua New Guinea, is described. Ecological studies that have been carried out are reviewed. Based upon the results of surveys on Mt. Giluwe, the role of *Phytophthora cinnamomi* in contributing to the dieback is examined. A comparison is made of *Nothofagus* dieback on Mt. Giluwe with *Metrosideros* dieback in Hawaii.

AN IMPORTANT COMPONENT of the midmontane forest zone of New Guinea is *Nothofagus* Blume (Johns 1982), and about 13 species are represented (Ash 1982). On Mt. Giluwe, an extinct shield-shaped volcano in the southern highlands of Papua New Guinea (Figure 1), three species of *Nothofagus*, *N. grandis* Steen, *N. rubra* Steen, and *N. pullei* Steen, are found, with *N. pullei* extending to a higher altitude than the other two species (Ash 1982). Extensive stands of single species may be formed, and there is a mosaic of small areas of trees, each dominated by a single size class that is apparently even-aged (Ash 1975).

A feature of these stands, and of stands of *Nothofagus* in other parts of Papua New Guinea, is the occurrence of patches of dead and dying mature *N. pullei* and *N. grandis* of large diameter (Ash 1982, Cartledge, Shaw, and Stamps 1975, Paijmans 1976). Death of trees is preceded by defoliation of the crown and development of epicormic shoots on the bole and lower crown. Initially, only a few trees die, but the patch may enlarge laterally at a rate of up to 5 m/yr (Ash 1975). Good regeneration of *Nothofagus* has been recorded in old dead patches, and there have been no symptoms of widespread mortality among the regrowth. Figures 2 and 3 show typical dieback patches.

Several hypotheses have been proposed regarding the cause of this dieback phenomenon (Ash 1982, Cartledge, Shaw, and Stamps

1975, Paijmans 1976, Robbins and Pullen 1965), and these are examined in this paper in conjunction with results obtained from a soil survey for root pathogens carried out at Mt. Giluwe.

DIEBACK: A NATURAL PHENOMENON?

The hypothesis that dieback is a natural phenomenon necessary for the regeneration of *Nothofagus* is one of two hypotheses, the other being that the dieback is a result of attack by a root pathogen newly introduced into the area (Cartledge, Shaw, and Stamps 1975). It has been observed that regeneration of *Nothofagus* spp. is generally poor under closed-canopy forests, with other species being favored (Ash 1975). Although seed crops may be heavy, very few seedlings develop and their growth is very slow. Upon opening of the canopy, seedlings grow rapidly, suggesting that they are light-demanding. In addition to seedlings, much regeneration originates from suckers which may arise from fallen tree trunks (Ash 1982). Thus, the regeneration of *Nothofagus* spp. appears to depend on the creation of gaps in the canopy, either through deaths of trees or by other means.

Mortality is restricted to trees of large diameters. Ash (1975) has shown that canopy closure occurs at about age 75 yr, maximum growth occurs at approximately age 150–200 yr, and senescence commences after this age. Groups of trees appear to be even-aged, representing a single cohort of individuals.

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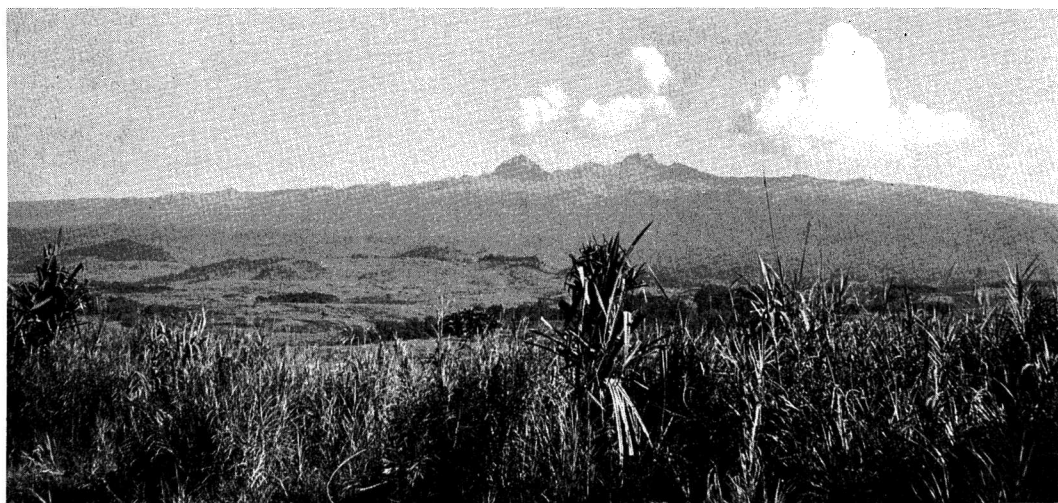


FIGURE 1. General view of Mt. Giluwe, an extinct shield-shaped volcano in the southern highlands of Papua New Guinea (height over 4000 m).



FIGURE 2. View of a patch of dieback in *Nothofagus* on Mt. Giluwe.



FIGURE 3. Same general area as shown in Figure 2, showing good regeneration of *Nothofagus* toward the top of the ridge on the right-hand side.

Thus, patch dieback may be a function of the simultaneous senescing of canopy cohorts, which may be a prerequisite for the regeneration of *Nothofagus* (Ash 1982, Mueller-Dombois 1982). In this hypothesis it is recognized that biotic agents, such as insects or fungal pathogens, may play a secondary role in enhancing tree senescence.

DIEBACK: OF PATHOGENIC ORIGIN?

The recovery of the A_1 mating type of *Phytophthora cinnamomi* from soil taken from dead patches on Mt. Giluwe, and its apparent absence from healthy forest, strengthened the hypothesis that *Nothofagus* dieback was of pathogenic origin (Cartledge, Shaw, and Stamps 1975, Shaw, Cartledge, and Stamps 1972). Its apparent absence elsewhere in Papua New Guinea (Cartledge, Shaw, and Stamps 1975) suggested that this mating type

of *P. cinnamomi* was a relatively recent introduction to this country. Similarly, the symptoms of dieback in *Nothofagus* were consistent with the effects of a recently introduced pathogen. Arentz and Simpson (1984) have now reported that the A_1 mating type of *P. cinnamomi* is widely distributed in other parts of Papua New Guinea and that it appears to be of early origin to the country. *Phytophthora cinnamomi* has also been recovered from under healthy *Nothofagus* on Mt. Giluwe (Table 1). In this study, 100 soil samples were collected from transects and plots in dieback patches, and 150 soil samples from healthy forest showing no manifest disease symptoms. A total of 47 isolates of the A_1 mating type of *P. cinnamomi* were obtained from the soil samples, 43 from under healthy forest and 4 from dieback patches. Nineteen of the 43 isolates from healthy forest came from 25 soil samples collected from a recently logged stand. One unidentified *Phytophthora* sp. was

TABLE 1

RECOVERY OF *Phytophthora cinnamomi* FROM *Nothofagus* FOREST, MT. GILUWE

SAMPLING TECHNIQUE	HEALTHY FOREST	DIEBACK PATCHES
Transects	50 soil samples 13 +ve for <i>P. cinnamomi</i> , A ₁	40 soil samples 1 +ve for <i>P. cinnamomi</i> , A ₁
Random sampling	25 soil samples 2 +ve for <i>P. cinnamomi</i> , A ₁	10 soil samples 2 +ve for <i>P. cinnamomi</i> , A ₁
Square plots, undisturbed forest	50 soil samples 9 +ve for <i>P. cinnamomi</i> , A ₁	50 soil samples 1 +ve for <i>P. cinnamomi</i> , A ₁ 1 +ve for <i>Phytophthora</i> sp.
Square plots, logged forest	25 soil samples 19 +ve for <i>P. cinnamomi</i> , A ₁	—

also recovered from a dieback patch (Arentz and Simpson 1984). Attempts to isolate *P. cinnamomi* directly from the roots were not successful. Thus, circumstantial evidence would suggest that *P. cinnamomi* does not play a primary role in causing patch dieback in *Nothofagus*.

DISCUSSION

From the literature it appears that the pattern of dieback of *Nothofagus* forest in Papua New Guinea is analogous to dieback in 'ōhi'a (*Metrosideros polymorpha* Gaud.) in Hawaii. The history of research into 'ōhi'a dieback has been reviewed by Mueller-Dombois (1980). The pattern of dieback is similar to that observed for *Nothofagus* (Mueller-Dombois 1982), and *Phytophthora cinnamomi* has also been recovered from soil from both healthy and declining 'ōhi'a stands as well as directly from the roots of dying 'ōhi'a trees (Kliejunas and Ko 1976). Good regeneration has been observed in the dieback areas, and the phenomenon is seen as a mechanism by which 'ōhi'a is able to rejuvenate (Mueller-Dombois 1980). The hypothesis that has evolved from this work is that the cause of the dieback is not due to a newly introduced insect pest or fungal pathogen, but is a natural phenomenon in which dieback is triggered by climatic instability in conjunction with interacting

environmental stress factors operating on the tree (Mueller-Dombois 1980). No detailed studies have yet been carried out into the *Nothofagus* dieback phenomenon in Papua New Guinea, and the hypotheses on the cause of dieback have been developed largely on the basis of superficial observations. The suggestion that a *Nothofagus* forest is composed of a large number of even-aged stands, or cohorts, and that canopy gaps are required for successful regeneration of the forest has not been confirmed. Although Ash (1975) found a restricted range of trunk diameter classes in stands of all three *Nothofagus* species on Mt. Giluwe, which suggested even-aged stands, this has been contradicted by Kalkman and Vink (1970), who reported a normal size class distribution in stands of *N. rubra* at Doma Peaks (an area to the west of Mt. Giluwe), indicative of uneven-aged stands. They further concluded that *N. rubra* was able to regenerate under its own cover. Similarly, the conclusion that *P. cinnamomi* may not be a primary pathogen causing *Nothofagus* dieback is speculative, since the fungus has been shown to be pathogenic to 2-yr-old plants of *N. cunninghamii* (Hook) Oerst. in Australia (Weste 1975). Also, other pathogens may be involved in causing *Nothofagus* dieback. For example, fruiting bodies of the root rot *Armillariella* have been collected from dead and dying *N. pullei* on Mt. Giluwe (Simpson, personal communication). More work will be



FIGURE 4. Prop roots of *Nothofagus*; litter layer is suspended above the mineral layer.

required to find the hosts of *P. cinnamomi* in the *Nothofagus* forests and to determine the pathogenicity of *P. cinnamomi* on these hosts.

An additional factor that may have to be taken into account is the possibility of relatively recent changes in climatic patterns in the area, triggering dieback in mature *Nothofagus* as a result of new stresses on the trees.

One serious disadvantage in formulating a hypothesis is the absence of any historical records for the region prior to the late 1920s. However, if it is accepted that patch dieback in *Nothofagus* is not a new phenomenon, then it becomes necessary to determine which factors trigger the dieback. It is proposed that nutrient deficiency is a primary trigger for tree senescence and dieback of *Nothofagus* trees on Mt. Giluwe.

Mature *Nothofagus* trees on Mt. Giluwe have been observed to develop prop roots (Figure 4), and it is suggested that the bulk of the feeder roots are restricted to the humus layer which may be suspended well above the

inorganic soil layer. Most of the nutrients utilized by the tree would be obtained from this humus layer, and these nutrients would be subjected to continual leaching. Normally, replenishment of nutrients would be from the inorganic soil horizons, but this would become greatly reduced as the tree matures and the feeder roots become more restricted to the humus layer. Consequently, nutrient availability would become limited, resulting in stress in the tree and predisposing the tree to attack by insects and root pathogens. The result is death of the tree or groups of trees linked through root grafting.

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LITERATURE CITED

- ARENTZ, F., and J. A. SIMPSON. 1984. The distribution of *Phytophthora cinnamomi* in Papua New Guinea. Ms. to be submitted to Trans. British Mycol. Soc.
- ASH, J. 1975. The ecology of *Nothofagus* and mixed species forests on S.E. Mt. Giluwe, Papua New Guinea. Report by the Department of Biogeography and Geomorphology, Australian National University, Canberra, Australia.
- . 1982. The *Nothofagus* Blume (Fagaceae) of New Guinea. Pages 355–380 in J. L. Gressitt, ed. Ecology and biogeography of New Guinea. W. Junk, Publishers, The Hague.
- CARTLEDGE, E. G., D. E. SHAW, and D. J. STAMPS. 1975. Studies in relation to dead patches of *Nothofagus* in Papua New Guinea. Dept. Agric. Stk. Fish., Port Moresby, Res. Bull. 13:1–26.
- JOHNS, R. J. 1982. Plant zonation. Pages 309–330 in J. L. Gressitt, ed. Ecology and biogeography of New Guinea. W. Junk, Publishers, The Hague.
- KALKMAN, C., and W. VINK. 1970. Botanical exploration in the Doma Peaks region, New Guinea. Blumea 18(1):87–135.
- KLIEJUNAS, J. T., and W. H. KO. 1976. Association of *Phytophthora cinnamomi* with ohia decline on the island of Hawaii. Phytopathology 66(2):116–121.
- MUELLER-DOMBOIS, D. 1980. The 'ōhi'a dieback phenomenon in the Hawaiian rain forest. Pages 153–161 in J. Cairns, Jr., ed. The recovery process in damaged ecosystems. Ann Arbor Science Publishers, Ann Arbor, Mich.
- . 1982. Dieback in tropical montane rain forests: Hawaii and Papua New Guinea. In Proceed. 25th Silver Jubilee Symp. Intern. Soc. for Trop. Ecol. (In press.)
- PAIJMANS, K. 1976. Vegetation. Pages 23–105 in K. Paijmans, ed. New Guinea vegetation. Australian National University Press, Canberra.
- ROBBINS, R. G., and R. PULLEN. 1965. Part VII. Vegetation of the Wabag-Tari area. Pages 100–115 in General report on lands of the Wabag-Tari area, Papua New Guinea. CSIRO, Austral., Lands Res. Ser. 15.
- SHAW, D. E., E. G. CARTLEDGE, and D. J. STAMPS. 1972. First records of *Phytophthora cinnamomi* in Papua New Guinea. Papua New Guinea Agric. J. 23:46–48.
- WESTE, G. 1975. Pathogenicity of *Phytophthora cinnamomi* towards *Nothofagus cunninghamii*. Austral. J. Bot. 23:277–283.